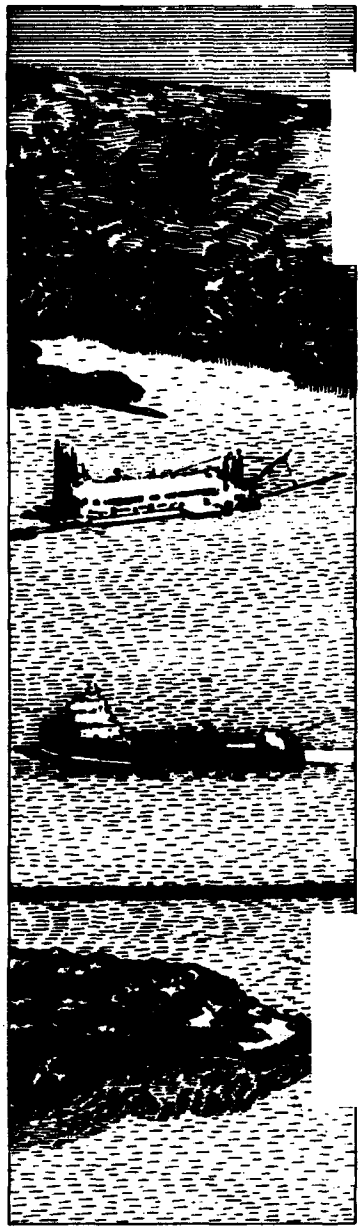
US Army Corps of Engineers



DREDGING RESEARCH PROGRAM

INSTRUCTION REPORT DRP-94-1

DREDGABL: GEOTECHNICAL FACTORS IN DREDGEABILITY

User's Guide

by

S. Joseph Spigolon

SJS Corporation
2220 No. 13th Court
Coos Bay, Oregon 97420

Reda M. Bakeer

Department of Civil and Environmental Engineering
Tulane University
New Orleans, Louisiana 70118

September 1994
Final Report

Prepared for DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32471

Monitored by U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

The Dredging Research Program (DRP) is a seven-year program of the U.S. Army Corps of Engineers. DRP research is managed in these five technical areas:

Area 1 - Analysis of Dredged Material Placed in Open Water
Area 2 - Material Properties Related to Navigation and Dredging
Area 3 - Dredge Plant Equipment and Systems Processes
Area 4 - Vessel Positioning, Survey Controls, and Dredge Monitoring Systems
Area 5 - Management of Dredging Projects

Dredging Research Program Report Summary

US Army Corps of Engineers
Waterways Experiment Station

DREDGABL: Geotechnical Factors in Dredgeability; User's Guide (IR DRP-94-1)

ISSUE: Geotechnical engineers, dredging estimators, and dredging contractors often do not understand each other's needs, site investigation methods, and vocabulary. Inevitable turnover in personnel means the loss of the knowledge of experienced and talented persons. These factors often lead to misinterpretation of the nature and extent of the sediments to be dredged.

RESEARCH: Knowledge-based expert systems (KBES) are computer programs that use a knowledge base of expert-derived rules for providing guidance. Rules in the knowledge base are in the form of "IF-THEN" statements that can incorporate judgement, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. The database of rules of a KBES is independent of the inference engine (program control); therefore, the ability to add new or expanded knowledge to the knowledge base is a major feature of a KBES.

The KBES described in this report is an outgrowth of a Dredging Research Program (DRP) work unit that involves the development of geotechnical descriptors to indicate, or infer, dredgeability of sediments to be dredged. The initial knowledge base was based on literature surveys, personal experiences, and comments made during several workshops.

SUMMARY: The Geotechnical Factors in DREDGeABiLity (DREDGABL) Program provides guidance in the interpretation of geotechnical descriptors of sediments in terms of their dredgeability properties. It is intended to be used by engineers, estimators, and contractors, serving as a personal geotechnical engineering consultant.

AVAILABILITY OF REPORT: The report is available through the Interlibrary Loan Service from the US Army Engineer Waterways Experiment Station (WES) Library, telephone number (601) 634-2355. National Technical Information Service (NTIS) report numbers may be requested from WES Librarians.

To purchase a copy of the report, call NTIS at (703) 487-4780.

About the Authors: Dr. S. Joseph Spigolon is an engineering consultant, SJS Corporation, Coos Bay, OR, and Dr. Reda M. Bakeer is an Associate Professor, Department of Civil and Environmental Engineering, Tulane University, New Orleans, LA. The study was conducted under the technical oversight of Dr. Jack Fowler, Principal Investigator, Geotechnical Laboratory, WES. For further information about the DRP, contact Mr. E. Clark McNair, Jr., Manager, DRP, at (601) 634-2070.

September 1994

Dredging Research Program

Instruction Report DRP-94-1
September 1994

DREDGABL: Geotechnical Factors in Dredgeability

User's Guide

by S. Joseph Spigolon

SJS Corporation
2220 No. 13th Court
Coos Bay, OR 97420

Reda M. Bakeer

Department of Civil and Environmental Engineering
Tulane University
New Orleans, LA 70118

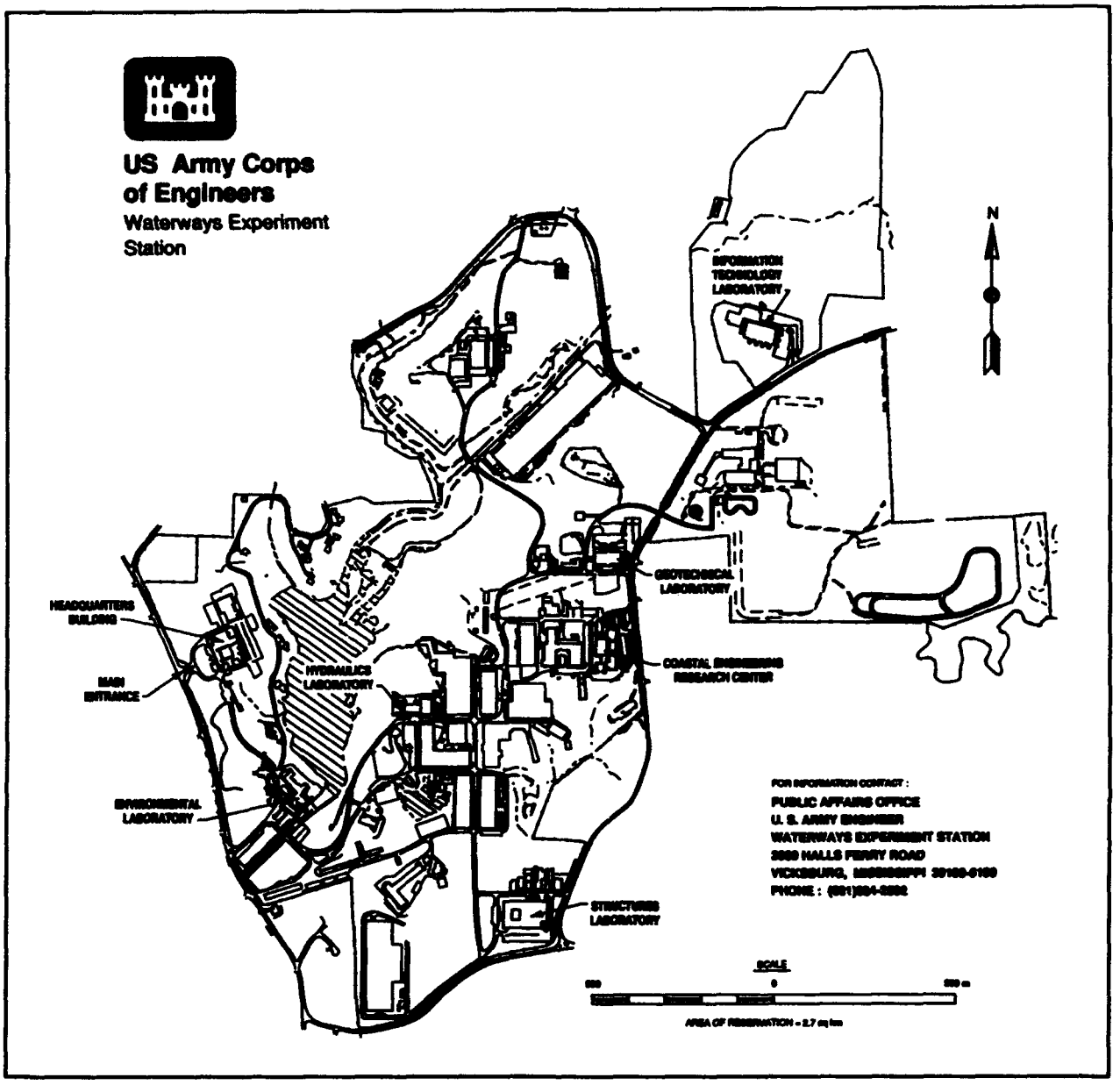
Final Report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under DRP Work Unit 32471

Monitored by U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199



Waterways Experiment Station Cataloging-in-Publication Data

Spigolon, S. J.

DREDGABL : geotechnical factors in dredgeability user's guide / by S. Joseph Spigolon, Reda M. Bakeer ; prepared for U.S. Army Corps of Engineers ; monitored by U.S. Army Engineer Waterways Experiment Station.

45 p. : ill. ; 28 cm. – (Instruction report ; DRP-94-1)

1. Dredging -- Computer programs -- Handbooks, manuals, etc. 2. DREDGABL (Computer program) – Handbooks, manuals, etc. 3. Marine sediments -- Computer programs -- Handbooks, manuals, etc. 4. Knowledge acquisition (Expert systems) I. Bakeer, Reda M. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Dredging Research Program. V. Title. VI. Title: Geotechnical factors in dredgeability user's guide. VII. Series: Instruction report (U.S. Army Engineer Waterways Experiment Station) ; DRP-94-1

TA7 W34i no.DRP-94-1

Contents

List of Figures

List of Tables

Preface

This user's guide and the associated computer program were prepared under Contract No. DACW39-92-C-0098 (Neg.), dated 22 July 1992, for the US Army Engineer Waterways Experiment Station (WES) under Dredging Research Program (DRP) Technical Area 2, Work Unit No. 32471, "Descriptors for Bottom Sediments to be Dredged." The DRP is sponsored by Headquarters, US Army Corps of Engineers (HQUSACE). Technical Monitor for Technical Area 2 was Mr. Barry W. Holliday; Chief Technical Monitor was Mr. Robert H. Campbell.

This user's guide was written by Dr. S. Joseph Spigolon, Engineering Consultant, Coos Bay, Oregon, and Dr. Reda M. Bakeer, Associate Professor, Department of Civil and Environmental Engineering, Tulane University, New Orleans, LA, under the technical oversight of Dr. Jack Fowler, Principal Investigator, Soil Mechanics Branch (SMB), Soil and Rock Mechanics Division (S&RMD), Geotechnical Laboratory (GL), WES. Mr. W. Milton Myers, Chief, SMB, GL; Dr. Don C. Banks, Chief, S&RMD, GL; and Dr. W. F. Marcuson III, Director, GL. Dr. Banks was also the Manager for Technical Area 2, "Material Properties Related to Navigation and Dredging," of the DRP. Mr. E. Clark McNair, Jr. and Dr. Lyndell Z. Hales were Manager and Assistant Manager, respectively, of the DRP, Coastal Engineering Research Center (CERC), WES. Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., were Director and Assistant Director, respectively, of CERC, which oversees the DRP.

During the publication of this report, COL Bruce K. Howard, EN, was Commander of WES. Dr. Robert W. Whalin was Director.

For further information concerning this report, contact Dr. Jack Fowler, (601) 634-2703, or Mr. E. Clark McNair, Jr., (601) 634-2070.

1 Introduction

This user's guide contains instructions for installing and using DREDGABL (Geotechnical Factors in Dredgeability), a knowledge-based expert system (KBES) for the geotechnical evaluation of the dredgeability of sediments. The two diskettes for the Microsoft Windows® version of DREDGABL are included with each copy of the user's guide; a limited number of the MS-DOS® version are available on request to Ms. Gloria Naylor, Scientific and Engineering Applications Center, Information Technology Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180 (CEWES-IM-DS).

Objective of DREDGABL

The accumulated knowledge and experiences of experts in a specific discipline can be recorded in a knowledge base which is then available for use in the solution of a specific set of problems in that discipline. A KBES is a computer program that provides guided interaction between a user and the knowledge base. The interaction is in the form of IF - THEN statements. The user is questioned about the problem context (IF-conditions) after which the KBES displays its expert-derived solution (THEN-conclusion).

The objective of DREDGABL is to provide guidance, from geotechnical engineering and dredging experts, in the form of KBES, for the interpretation of sediment test and observation data in terms of the dredgeability of the sediment. DREDGABL is intended for use by dredging project estimators and planners working with the U.S. Army Corps of Engineers, dredging contractors, or dredging consultants. It can also show, to the geotechnical engineers and engineering geologists involved in dredging project site investigation, what the important sediment properties are for dredgeability evaluation.

Program Overview

DREDGABL provides an expert evaluation of the dredgeability characteristics of specific sediments whose geotechnical properties are described in the dredging contract documents. Advice is also given about the suitability of various types of dredging equipment for use with those sediments, based on dredgeability characteristics. Expert knowledge is contained in several knowledge databases that are queried during operation of the program.

Two parallel and equal versions of the DREDGABL program have been developed. One operates in the conventional Microsoft Disk Operating System (MS-DOS)® environment and the other runs under the Microsoft Windows® environment. Knowledge databases, control programs, and inferencing mechanisms for both versions are identical. Input and conclusion screen displays are also identical, except that the screen displays in the MS-DOS version are character-based and in the Microsoft Windows version they are graphics-based.

Both the MS-DOS and the Windows versions for DREDGABL are user-friendly and support mouse input. Input is provided through a group of consultation screens, each containing a question with multiple-choice answers. Answers and/or screen controls are selected by mouse-pointer clicking or by the keyboard arrow keys and keystroke combinations. This eliminates the need for the user to type words or numbers for data input during guidance sessions. This is intended to accelerate the input process, eliminate typographical errors, and facilitate the use of the system by non-typists. The path through the input screens is not fixed; the question asked on each new screen is the result of the specific answer to the question posed on the previous screen.

DREDGABL starts with the assumption that the available sediment geotechnical descriptor data are contained in the project plans and specifications in the American Society for Testing and Materials (ASTM) (ASTM 1993) format which is based on the Unified Soil Classification System (USCS) (USAEWES 1960). The flow of the program through the group of display screens is shown on Figure 1.

Briefly, the overall strategy of the DREDGABL program is:

a. The first question requests the general type of sediment in the layer or deposit being evaluated. The general sediment type is defined as the predominant material found in the sediment to be dredged, or as the material corresponding to the median grain size, d_{50}.

b. If the sediment type if gravel or sand, DREDGABL requests the USCS/ASTM classification, sediment name, compactness, gradation fineness, and grain angularity.

c. If the sediment type if inorganic fines or organic fines, DREDGABL requests the USCS classification, sediment name, consistency, and plasticity index. If the consistency is UNKNOWN, and the water content is known or the wetness known, then it may be possible to estimate the consistency from the liquidity index.

d. If the sediment type is in the other sediments category, then only the sediment name is required to identify the material. Properties of these materials may vary significantly and there are no specific designations for them either in ASTM or USCS.

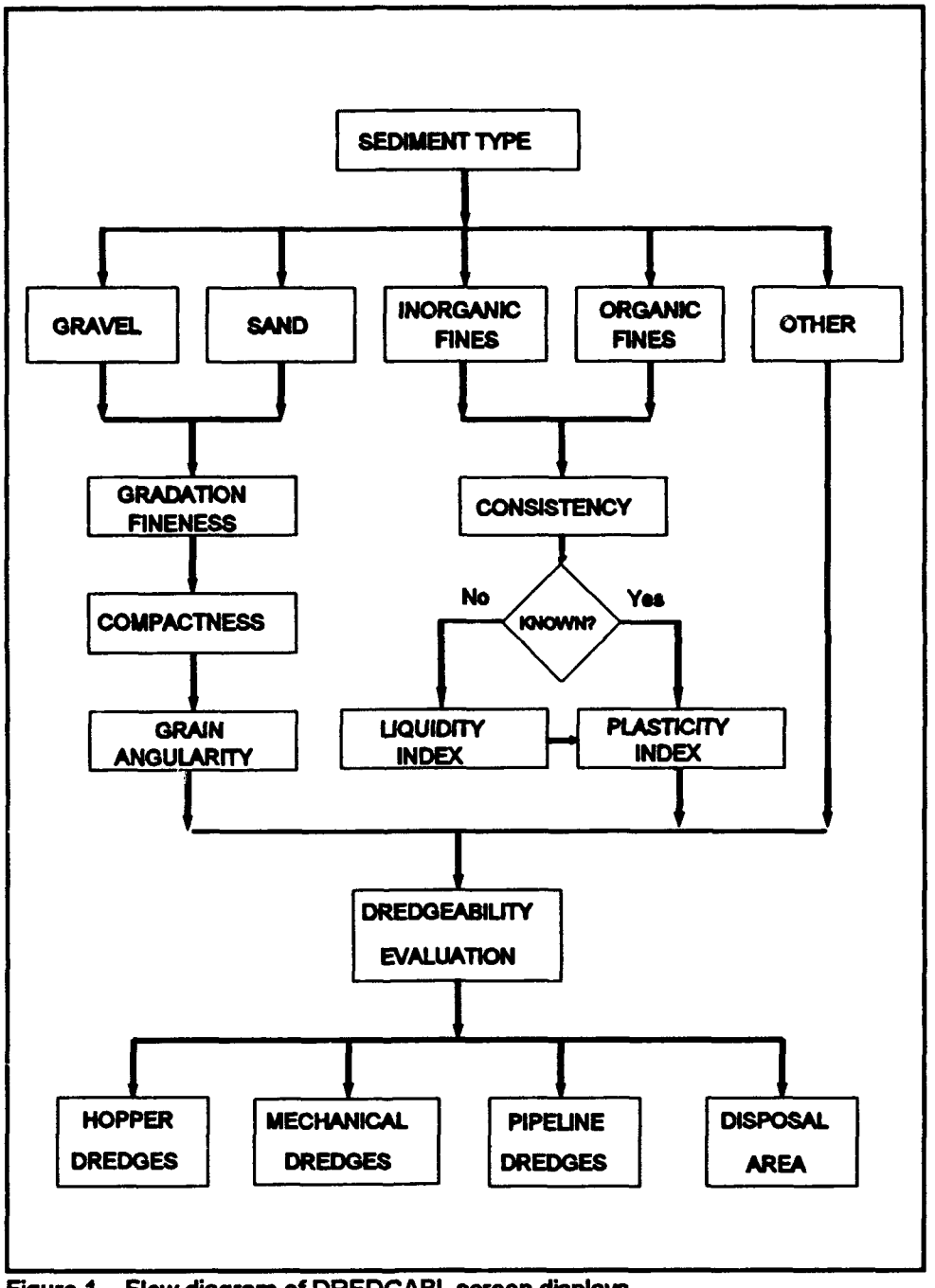


Figure 1. Flow diagram of DREDGABL screen displays

e. After all required antecedents are defined (including the possible choice of "Unknown" in any category), DREDGABL evaluates this information and searches the appropriate knowledge base for conclusions about the dredgeability properties of the uniquely described sediment.

f. The user may then display DREDGABL's conclusions about the suitability of various generic types of hopper, mechanical, and pipeline dredges for use with the described sediment, or may display the disposal area properties. The user may also choose to print out the complete set of conclusions for the specific sediment.

g. Provision has been made in DREDGABL for the recording of information and knowledge about, and experiences with, local sediments that have been developed by the user's organization. This is locally-derived information that amplifies or supersedes the information contained in the general knowledge bases. The LOCAL INFO database may be viewed and the contents of any memorandum may be printed.

In the present version, DREDGABL considers only one sediment type at a time in its evaluation of the suitability of various dredge types for that sediment. Therefore, the user must run the DREDGABL program again for each layer or deposit in the dredging prism having a unique set of properties.

Background

The KBES computer program described herein was developed as part of the WES Dredging Research Program (DRP) Work Unit No. 32471, "Descriptors for Bottom Sediments to be Dredged." The objective of the work unit is to develop standard dredging-related geotechnical descriptors for indicating, or inferring, the dredgeability of sediments.

A KBES such as DREDGABL can serve one or more of the following purposes:

a. Guidance. As a guide, or computerized mentor, for those persons lacking knowledge and experience in the dredgeability analysis of geotechnical data.

b. Education. As an educational aid in the training of new dredging project planners, estimators, administrators, and operators.

c. Peer review. For peer review, where knowledgeable and experienced personnel can consult with other experts for review and as a cross-check on their own work.

Outline of User's Guide

Chapter 2 gives installation instructions for placing the DOS or the Windows version of DREDGABL on the user's hard disk. Instructions are also given for navigating through the screens.

Chapter 3 contains operating instructions for the DREDGABL program. A run-through of the input display and conclusion display screens and a description of the help (discussion) screen system are made. The local information database system is presented.

Chapter 4 presents a brief discussion of three background topics for users of the DREDGABL program. First, there is a general discussion of knowledge-based expert systems and the manner in which they function. Second, the rationale for selecting a relational database management system as the expert system development shell is presented. Third, the relationship of a KBES to a printed report is examined.

Chapter 5 discusses potential future modifications to the DREDGABL program. The requested review information is intended primarily for use by the programmer and administrators of the development version of DREDGABL. Also discussed are methods for modification and/or control of the LOCAL INFO database.

2 Installing DREDGABL

There are two equivalent versions of the DREDGABL program: the Windows version and the MS-DOS version. The versions differ only in the format of the display screen files. Windows screens are graphics-based and MS-DOS displays are character-based . Because of its graphical environment, the Windows version of DREDGABL contains graphics that are not available in the current MS-DOS version. The user may install both versions on the same computer, but in different directories.

(NOTE: DO NOT place the DOS and Windows version files in the same directory because they use the same screen file names. This will cause malfunction of the programs.)

Appendix A contains a listing of all files contained on the distribution diskettes for the Windows version and the DOS version of DREDGABL. If any of the listed files are missing from the diskettes, please contact the Manager of the Dredging Research Program at the address given in the Preface to this User's Manual.

System Requirements

Suggested minimum equipment requirements are:

a. 80386SX processor, or higher.

b. Mouse (not absolutely necessary, but highly useful).

c. Minimum of 4 Mb of random access memory (RAM); preferably 6 Mb of RAM for the Windows version.

d. MS-DOS version 3.1 or higher.

e. For the Windows version, Microsoft Windows version 3.1 or higher running in 386 enhanced mode..

f. At least 6 MB of free hard disk space for the Windows version. At least 4 MB of free hard disk space for the DOS version.

g. Standard video graphics adapter (VGA) monitor (640 x 480 pixels). NOTE: The program contains color screens and the Windows version uses color graphics. A monochrome monitor can be used but the images will be displayed in black and white. Other color monitors, such as Super VGA (SVGA), may be used but display quality may be affected.

Hard Disk Installation -- Windows Version

The Windows version of DREDGABL is contained in two 3.5-in. high-capacity (1.44 Mb) diskettes. The following steps should be taken to install the Windows (graphics-based) version of the program on a hard disk:

1. Insert Disk No. 1 of the DREDGABL (Windows version) diskettes in drive A (or drive B).

2. Start Windows (refer to the Microsoft Windows user's manual if necessary) or OS/2. In the **Program Manager** window, click the mouse on **FILE**. In the **FILE** menu, click the mouse on **RUN**.

3. In the **RUN** window command line, type A:\setup; then click on **OK**.

4. It may take several minutes before the Setup window appears. The files on the diskettes are compressed and are being decompressed. **Be patient; do not reboot the computer.**

5. When the Setup window is displayed, the user is asked to confirm, or to change, the hard drive letter, the directory name, and the Program Group in which to place DREDGABL. After this choice, Windows continues loading the program, asking for the other disks at the appropriate time.

6. At the completion of the setup (file decompression and loading) process, Windows places an icon marked "DREDGABL" in the chosen Program Group.

Hard Disk Installation -- DOS Version

The DOS version of DREDGABL is contained in two 3.5-in. high-capacity (1.44 Mb) diskettes. To install the program on drive d: (where d: is any desired hard drive) and the directory d:\DREDGDOS, insert DOS Disk No. 1 in drive A (or drive B) and type **A:INSTALL d a** (or B:INSTALL d a), where **d** is the target drive and **a** is the source drive. Type the command exactly as shown; do not use a colon (:) after the target or the source drive names. The installation batch file performs the following tasks automatically. If the batch file does not function properly, then the following operations can be done manually:

1. Create a directory named d:\DREDGDOS (or use any other directory name). Copy all files from the two DOS diskettes to the new hard disk directory. The files are in a compressed (archived) format.

2. For example, to install files from disk drive A: to hard disk C: in directory C:\DREDGDOS, type the following in order:

C:\	(Makes C the default drive)
md DREDGDOS	(Creates new directory)
cd DREDGDOS	(Moves to new directory)

   The new default drive is now C:\DREDGDOS. Place diskette No. 1 of the DOS version in Drive A: and enter

Copy A:*.*	(Copy all files on A to C:\DREDGDOS)

   When copying is completed, replace Disk 1 with Disk 2 and repeat:

Copy A:*.*	(Copy all files on A to C:\DREDGDOS))

3. Decompress (unarchive) the files. To unarchive, remain in the d:\DREDGDOS sub-directory and type, in turn, :

ARCE FOXDISTR	(FOXDISTR.ARC contains the Foxpro Distribution Kit operating files)

   and then

ARCE DREDGDOS	(DREDGDOS.ARC contains all of the DREDGABL files)

4. From within the d:\DREDGDOS directory, delete the FOXDISTR.ARC, DREDGABL.ARC, and ARCE.COM files from your hard disk; they are no longer needed! Do this by typing:

DEL ARCE.COM	(Deletes ARCE.COM)
DEL FOXDISTR.ARC	(Deletes FOXDISTR.ARC)
DEL DREDGABL.ARC	(Deletes DREDGABL.ARC)

Note: The DOS command ERASE performs the same function as DEL.

3 Operating the DREDGABL Program

To start the DREDGABL program:

a. For the Windows version, two choices are available:

1. While in the Windows Program Manager window, simply click on the DREDGABL icon; or

2. While in the Windows Program Manager window, open (click on) the **FILE** menu. In the **FILE** menu, click on **RUN**. The **RUN** command screen will appear. On the **RUN** Command Line, type

   d:\DREDGABL\DREDGABL

   or use the **BROWSE** button to locate the **DREDGABL.EXE** file.

b. For the DOS version, move to the d:\DREDGDOS directory. From the previous example, assume the DREDGABL program files are in the C:\DREDGDOS directory, and type:

DREDGABL

This activates a batch file that contains the necessary commands to start the DREDGABL program.

Navigating the DREDGABL Program

The following semi-tutorial presentation discusses the various input and conclusion screens contained in DREDGABL. It follows each of the several paths shown in Figure 1. The figures contain captured copies of Windows version graphical screens. The character-based DOS screens contain the same information, pose the same questions, and contain the same data-option choices, but do not have the Windows graphics effects and fonts.

The user interacts with DREDGABL through a series of display screens. The following five groups of screens are used:

a. Introductory displays. The introductory displays consist of the Title display, the Navigating Information display, the Purpose display, the Scope display, and the Disclaimer display.

b. Input displays.

c. Conclusion displays.

d. Text Explanation (Discussion) displays.

Display screen features

Each display screen contains one or two sets of control buttons. A button is activated by either of the following actions

a. Using a mouse to click on the button.

b. Using the keyboard arrow keys an/or the < TAB > key to highlight the preferred button and pressing < ENTER >.

Where options are presented for the user's choice of input data, activation of a DATA-OPTION button causes DREDGABL to acknowledge this as the user's choice and proceed to the next display screen. The bottom panel of each screen contains from one to four buttons, as needed, to alter the normal flow of questioning.

Title screen

The first screen to appear is the Title screen (Figure 2), providing two choices in the control bar at the bottom. For one or more runs, the user may choose to view the Introductory screens described above by activating the < INTRODUCTORY SCREENS > button. These are followed by the Choice screen.

As the user becomes familiar with the program, the introductory displays can be bypassed by activating the button marked < QUICK START >. This choice bypasses the Introductory screens and leads directly to the Choice screen.

Choice screen

After the Introductory screens are viewed or by-passed, the Choice screen (Figure 3) appears. The user must choose between two alternatives:

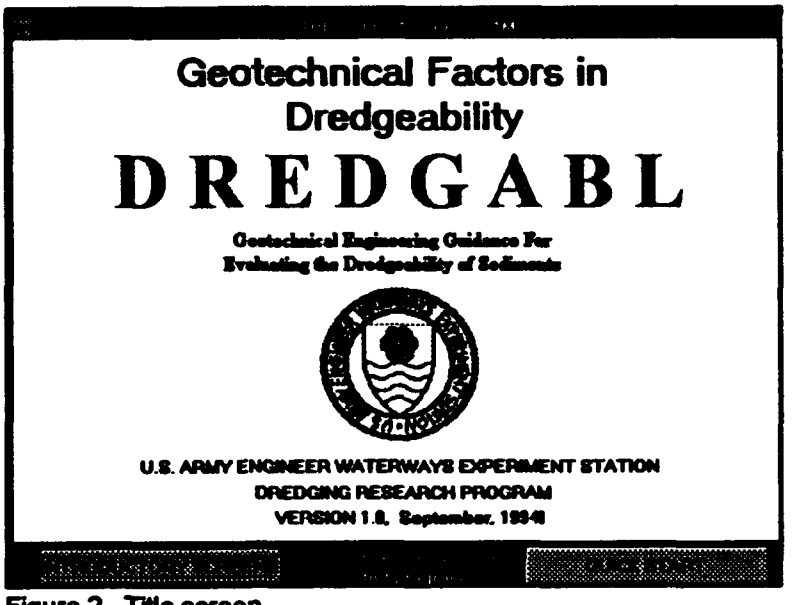


Figure 2. Title screen

a. If the user wishes to continue with DREDGABL for a conventional evaluation of the dredgeability of a specific sediment, the < EVALUATE > button is clicked with the mouse or selected with the arrow keys and < ENTER >.

b. If the user wishes instead to view the database of records of locally eveloped information, which is of local interest only (see discussion below), the < LOCAL INFO > button is activated.

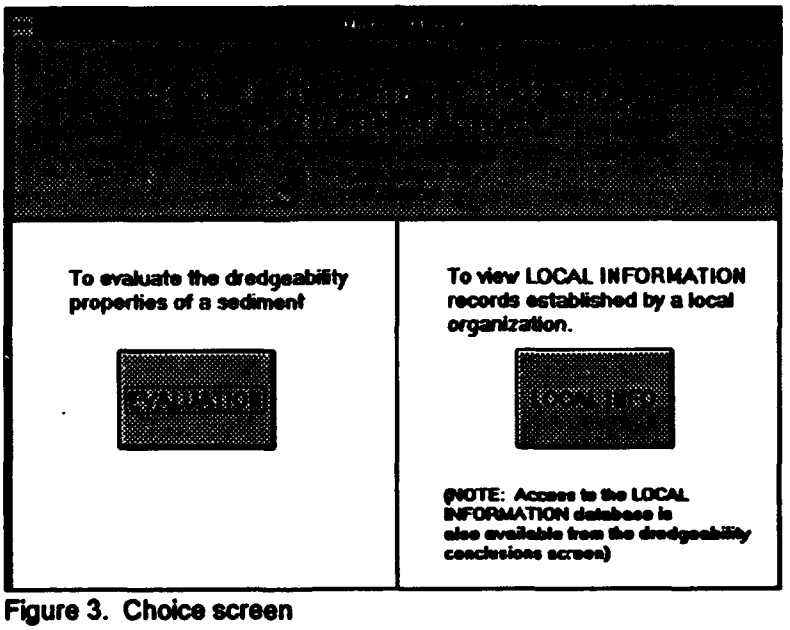


Figure 3. Choice screen

Using the Data Input Displays

In the flow diagram of Figure 1, the display screens from "Sediment Type" downward to "Dredgeability Evaluation" are DATA INPUT displays. Each input display contains a question asking for the value of one of the geotechnical parameters needed to reach a conclusion about the dredgeability of that sediment. Selections made in each of the input displays are maintained in Context memory until all of the needed antecedents for a specific sediment type are defined. Geotechnical antecedent properties used by the DREDGABL program are shown in Table 1.

Table 1
Geotechnical Antecedent Properties Used in DREDGABL

Sediment Type	Geotechnical Properties Used
Gravel Sand	1. USCS Classification 2. Sediment name 3. Gradation fineness 4. Relative compactness 5. Grain angularity
Inorganic Fines Organic Fines	1. USCS Classification 2. Sediment name 3. Relative consistency. 4. Plasticity Index 5. Liquidity Index (An estimator of consistency; used ONLY when the relative consistency is unknown)
Other Sediments	Generic name of sediment

Each of the data input displays contains an on-screen, scrollable information text presenting a brief discussion about the choices available on that specific display. More detailed discussions of these, and other topics, can be accessed by clicking on < DISCUSSION > at the bottom of a screen.

Sediment type display

On the first data input screen, shown in Figure 4, the question asked by DREDGABL is: "Which of the following GENERAL SEDIMENT types best describes the layer or deposit being evaluated?" The screen presents the following choices, one of which must be selected to continue:

a.	Gravel	USCS Classification gravel-series soils
b.	Sand	USCS Classification sand-series soils
c.	Inorganic Fines	Fine-grained soils: silt and clay
d.	Organic Fines	Fine-grained soils: organic silt, organic clay, peat

e. Other Sediments — Rock, coral, shale, cemented soils, boulders, cobbles, fluid mud, shells, debris.

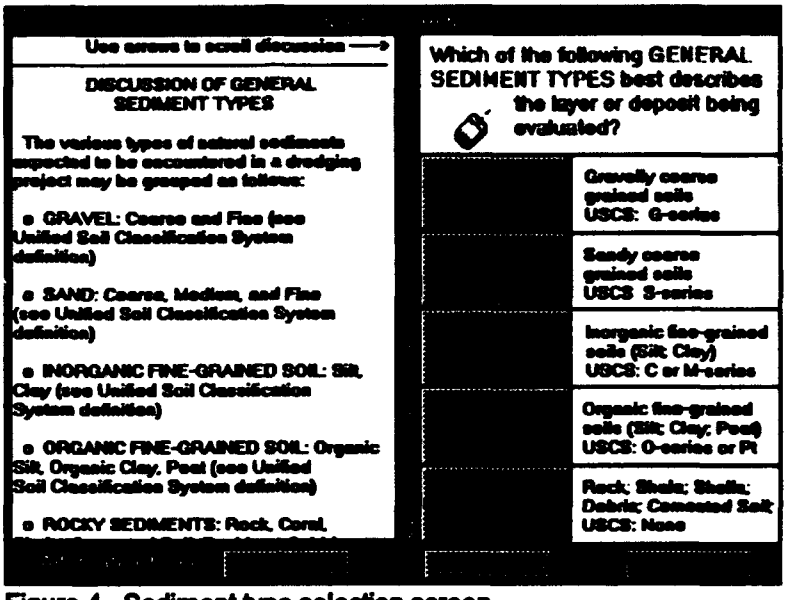


Figure 4. Sediment type selection screen

USCS classification and name of coarse-grained sediments display

If the sediment type is gravel or sand, the next input display asks for the USCS-ASTM Classification. Options are presented for all of the USCS-ASTM classes of each coarse-grained sediment type. Assuming the sediment type is a SAND, then selection must be made, in Figure 5, from the sand classification options offered

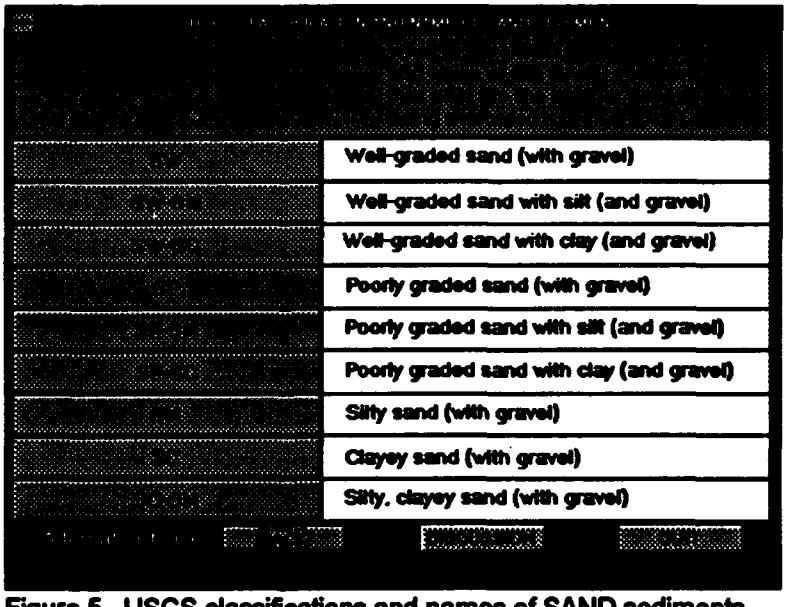


Figure 5. USCS classifications and names of SAND sediments

by the USCS. A similar screen is used for gravel. Activation of the VIEW button displays a screen of typical grain size distribution curves with explanatory text.

Gradation fineness display

If the sediment type is gravel or sand, the next input display asks for the gradation fineness. For gravel, this includes: Coarse, Fine, and Unknown. For sand, the options are: Coarse, Medium, Fine or Unknown. The gradation fineness display for sand is shown in Figure 6. An on-screen discussion text offers guidance on gradation fineness.

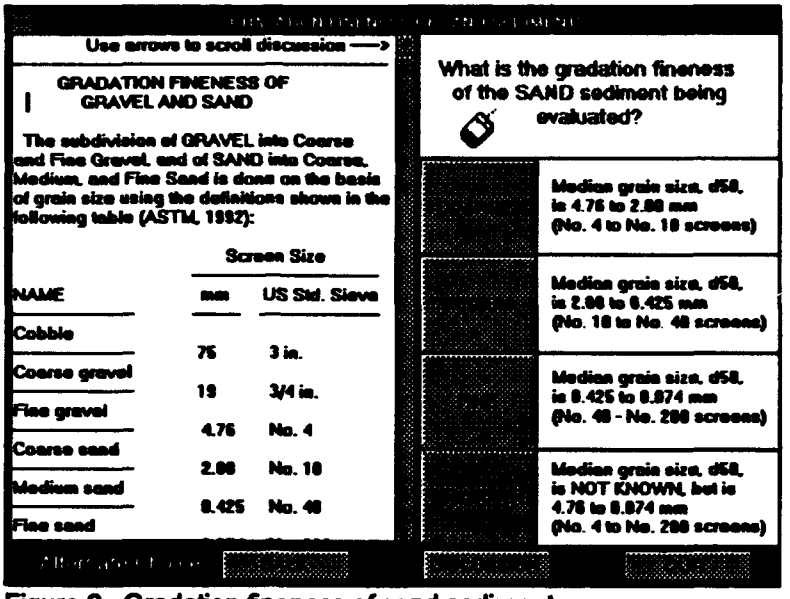


Figure 6. Gradation fineness of sand sediment

Compactness of coarse-grained sediments display.

The screen shown in Figure 7 requests the relative compactness of a coarse grained sediment. One of the choices is "Unknown." Standard Penetration Test (SPT) blow count values are shown for ready reference. However, see the DISCUSSION of Standard Penetration Test for a more refined method of interpreting SPT data.

Angularity of coarse grains display.

Figure 8 is the input display for selection of the grain angularity. Options are: Angular, Subangular, Subrounded, Rounded, and Unknown.

This terminates the antecedent-data collection for gravel or sand. The program now proceeds to the dredgeability evaluation menu screen.

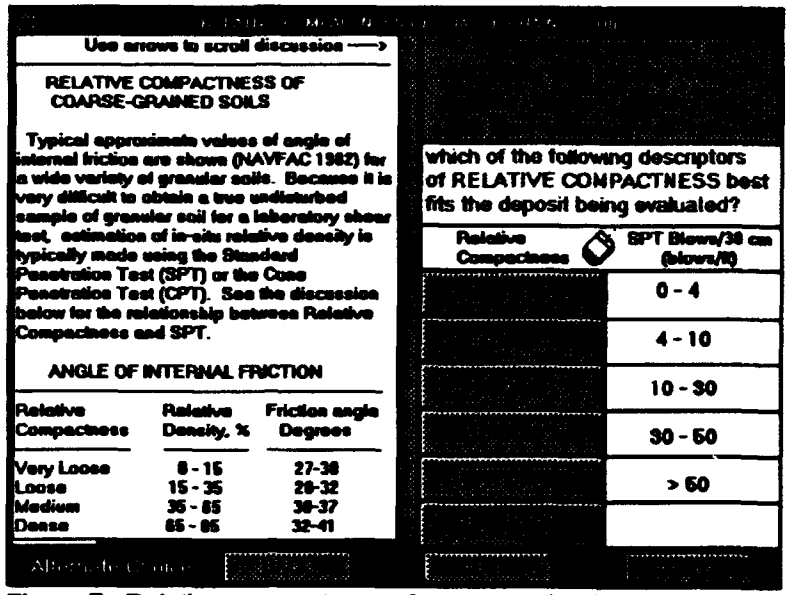


Figure 7. Relative compactness of coarse-grained sediment

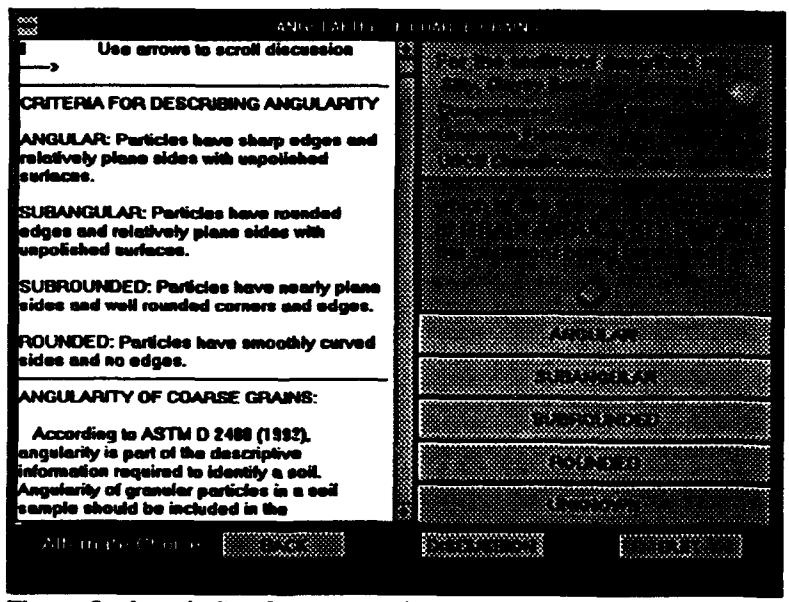


Figure 8. Angularity of coarse grains

USCS classification and name of fine-grained sediments display.

If the sediment type selected in Figure 4 is inorganic or organic fine-grained soil, i.e., silt or clay, the next input display asks for the USCS-ASTM Classification. Options are presented for all of the USCS-ASTM classes of each fine-grained sediment type. Assuming the sediment type is an INORGANIC CLAY, then selection must be made from the options displayed in Figure 9, which constitute all of the inorganic fines options offered by the USCS. A similar screen is used for organic fines.

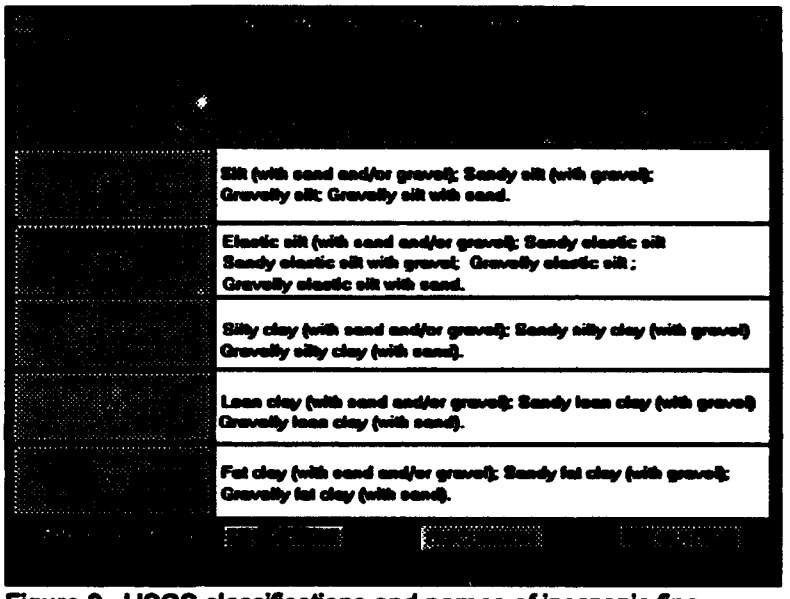


Figure 9. USCS classifications and names of inorganic fine-grained sediments

Relative consistency of fine-grained sediments display.

Figure 10 shows the Relative Consistency input display. A choice is made among the options of relative consistency (unconfined compressive strength): Very Soft, Soft, Medium, Stiff, Very Stiff, Hard, and Unknown. Corresponding values of unconfined compressive strength are displayed for the user's guidance.

Plasticity index of fine-grained sediments display.

DREDGABL uses four plasticity index categories in its rules: (1) 4 to 7, (2) less than 22, (3) 22 to 38, and (4) above 38. For the plasticity index input display, DREDGABL makes a decision about which of three plasticity index display screens to show, based on USCS classification. The screen for CL or OL (clay) is shown as Figure 11. No input display is used if the USCS classification is CL-ML because the plasticity index must, by definition, be 4 to 7, or if the USCS classification is ML or OL (silt) because the plasticity index must be less than 22.

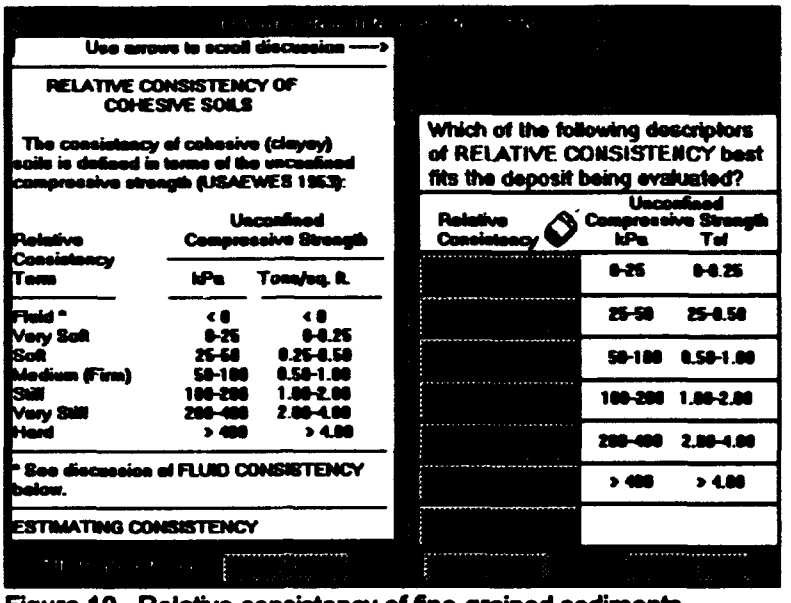


Figure 10. Relative consistency of fine-grained sediments

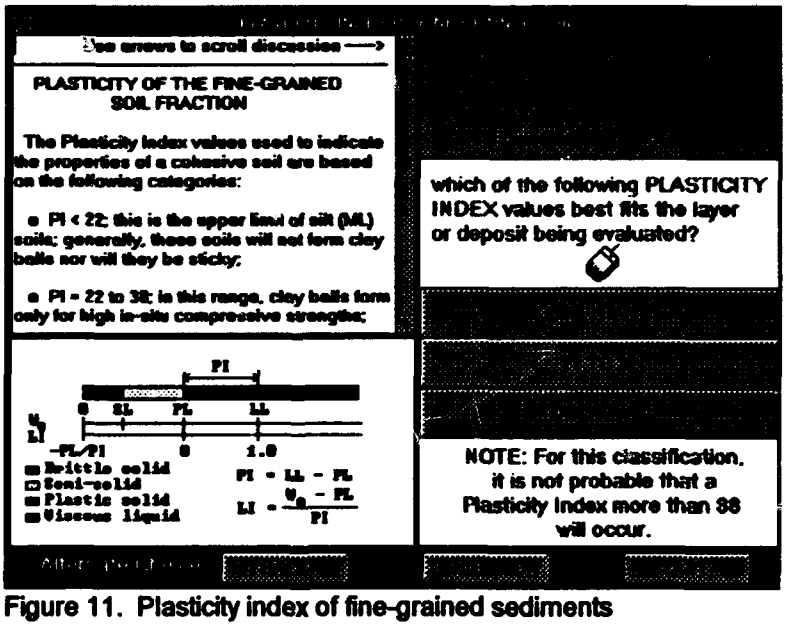


Figure 11. Plasticity index of fine-grained sediments

Liquidity index of fine-grained sediments display.

The liquidity index is calculated from the water content, and indicates a liquidity relative to the liquid and plastic limits of a remolded soil. It can be an indicator of relative consistency by itself or a useful cross-check on the measured relative consistency. If the consistency is known and has been indicated, the Liquidity Index display is bypassed to prevent a potential conflict of information. Therefore, Figure 12 is only displayed if the consistency selected in Figure 10 is "UNKNOWN."

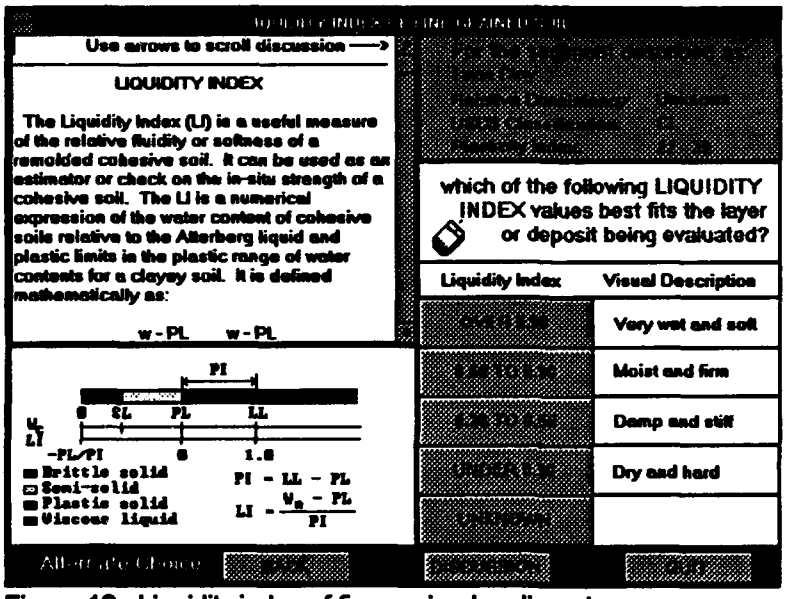


Figure 12. Liquidity index of fine-grained sediments

This terminates the antecedent-data collection for fine-grained sediments. The program now proceeds to the dredgeability evaluation menu screen.

Other sediments identification display.

If the chosen sediment type in Figure 4 is "Other Sediments," the next input display, Figure 13, requests a choice among the following sediment types: rock, coral, shale, cemented soils, boulders, cobbles, fluid mud, shells, or debris. At the present stage of development of DREDGABL, no other geotechnical properties are used in the dredgeability rules; therefore none are requested of the user and antecedent-data collection is terminated.

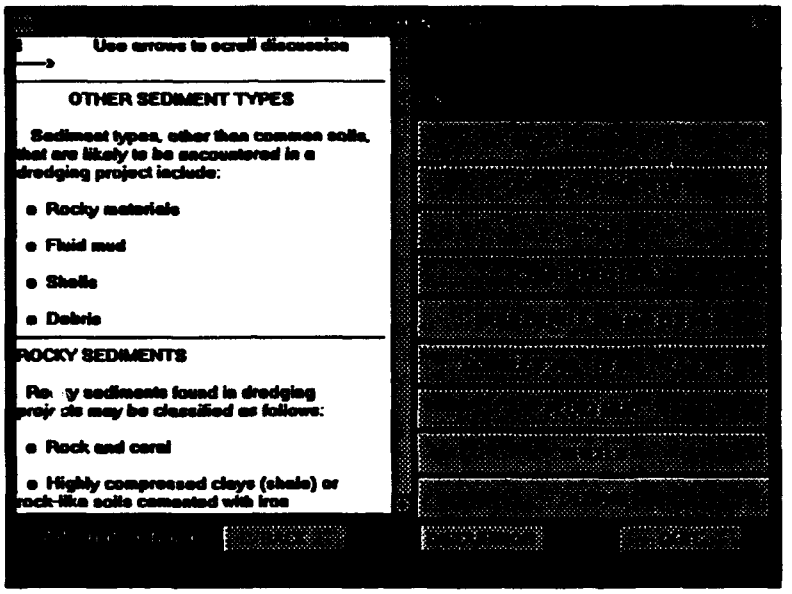


Figure 13. Selection screen for Other Sediments

Using the Conclusion Displays

In Figure 1, the four display screens following "Dredgeability Evaluation" are "Conclusion" displays. After the input displays have been used to define all of the necessary antecedent (IF statements) data from Table 1, the inferencing process starts, i.e., a query is made of the appropriate knowledge database, and an associated set of conclusions (THEN statements) is derived. The conclusion set is stored in the Conclusions Memory.

The conclusion sets chosen from the "Dredgeability Evaluation" display may be repeatedly viewed at random. The user may also choose to print the complete summary set of conclusions in a report. The context variables and the conclusion set are maintained in memory until the context is changed and a new inferencing process is triggered or until the program is ended.

After the appropriate entry of the required geotechnical data in the input displays, DREDGABL proceeds to the evaluation (inferencing) process and the storage of a unique set of conclusions in the Conclusions memory. The rules for evaluation operate internally in DREDGABL to consider all of that sediment's known geotechnical properties that affect each of the specific dredgeability mechanisms. An evaluation menu is displayed, Figure 14, that contains the following choices:

a. Hoppers (Suitability of hopper dredges)

b. Mechanical (Suitability of mechanical dredges)

c. Pipeline (Suitability of pipeline dredges)

d. Disposal (Disposal area properties of sediment)

e. Print Summary Report

f. Print/View Local Information Database

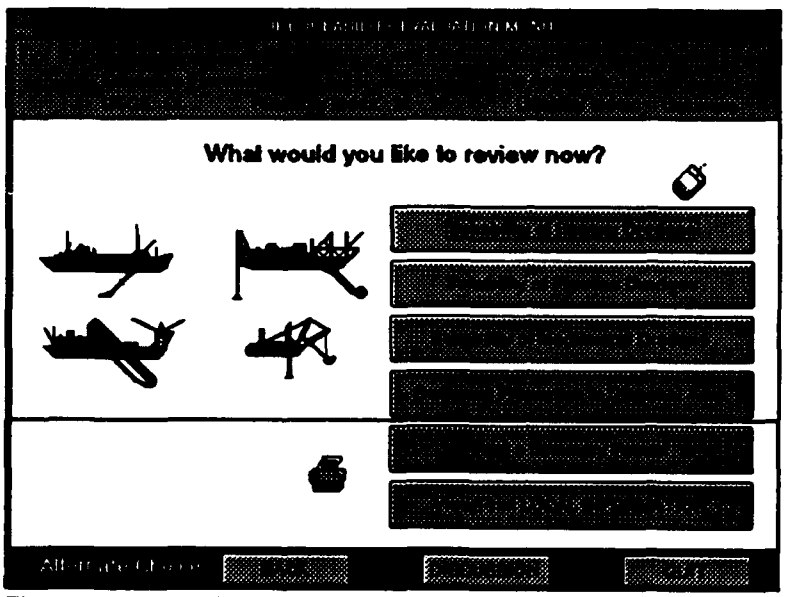


Figure 14. Menu for selection of conclusions display

Figure 15 is the conclusions display for hopper dredge suitability. It is typical of those for hoppers, mechanical, and pipeline dredges. A similar display presents conclusions about the disposal area properties of the described sediment. Disposal area properties are, of course, reasonably independent of the dredge type used for excavation and transport.

If the < **PRINT A SUMMARY REPORT** > button is activated in the Conclusions display menu, Figure 14, another display screen is activated, requesting information from the user: Date, Project, and User Name. The Summary Print display shows the status of the antecedents in the Context Memory. Then, a one-page summary showing all sediment-specific antecedents in Context Memory and all of the conclusions contained in Conclusions Memory is printed. The report contains all of the information that is displayed in the four dredge-suitability screens.

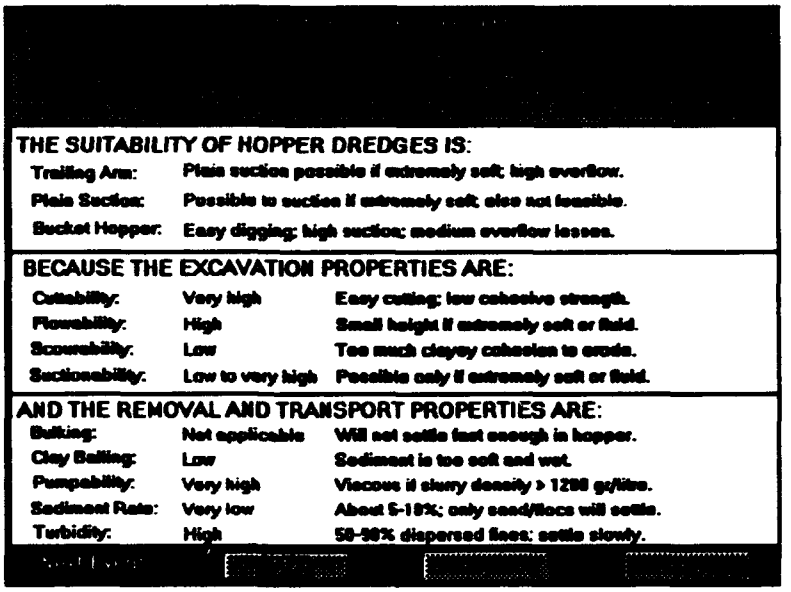


Figure 15. Conclusions display for hopper dredge suitability

Using the DISCUSSION Facility

Activation of the < *DISCUSSION* > button at the bottom of any of the displays causes a display of a menu of explanatory texts that pertain to dredgeability. Each text is intended to present a discussion of the antecedents (IF-statement) or an explanation of the conclusions (THEN-statement) and rules used in the knowledge bases. Care is taken to differentiate between factual information and the experts' interpretation(s) of the facts.

Because of the differences between the Windows graphical environment and the DOS character-based environment, two formats of the DISCUSSION facility are used. The text portion of both formats is identical. However, the Microsoft Windows version includes graphic line drawings and pictures that are not possible in the DOS version. The topics included in the present version of DREDGABL are listed in Table 2.

Windows-Style Discussion Facility

The Windows version discussion topics are displayed in the Windows format help facility database titled DRDGHELP.HLP. The Main Menu is first displayed, showing the major topic headings in green (or the default color of the HELP facility in your Windows setup). By clicking the mouse pointer on any of the major topics, a Sub-Menu for that topic is displayed. Clicking on any of these green colored topics will display the text and graphics of that topic.

Three control buttons at the top of the screen are used by Windows. The < BACK > button will cause a return to the previous screen. The Main Menu is accessed at any time by choosing the < CONTENTS > button. Clicking on the button marked < HISTORY > displays a record of all screens viewed during a "help" session.

There are two ways to EXIT the discussion facility. First, by either double-clicking on the (--) button at the upper left corner of the screen or by single-clicking the button and choosing "Close." The second method involves clicking on the word "File" in the Menu Bar, and then choosing "Exit."

The contents of any of the topics can be printed by clicking on the word "File" in the Menu Bar. Click on the menu choice of "Print Topic."

DOS-Style Discussion Facility

The DOS character-based discussion topics are contained in a Microsoft FoxPro 2.5 HELP-style database titled DRDGHELP.DBF. The format of the database of discussion topics is that dictated by the internal format of the FoxPro Help Facility. Clicking on "Topics" causes a display of the topics in the facility. The text of any topic can then be displayed by clicking on the topic name or by highlighting the topic name using a cursor and then pressing < ENTER >. The Discussion Facility may be exited by clicking on the upper left corner of the screen or by pressing the < ESC > button on the keyboard.

Using the LOCAL INFO Facility

A provision has been made on both the CHOICE menu (Figure 3) and the DREDGEABILITY EVALUATION menu (Figure 14) screens for accessing a separate database using the < LOCAL INFO > button. This knowledge database, if present, contains expert knowledge and information developed by, and of interest and value only to, a local user group. The local interest user group may be a Corps of Engineers District, a contractor's office, or a consultant's office.

Activation of the < LOCAL INFO > button on the Choice (Figure 3) screen or the < View/Print LOCAL INFORMATION > button on the Dredgeability Evaluation Menu (Figure 14) will activate the Local Information Selector screen, Figure 16. By using the buttons in the horizontal Database Control Bar in the upper center part of the screen, the titles and contents of the local information database, if any, are displayed. The LOCAL INFO knowledge base is, in effect, a database with

Table 2
Topics Available in the DREDGABL Discussion Facility

SEDIMENT DESCRIPTIONS
Description of General Sediment Types
Inorganic Fine-Grained Sediments
Organic Fine-Grained Sediments
Fluid Mud Sediments
Gravel Sediments
Rock, Coral, Shale, Cemented Soil, Boulders, and Cobbles
Sand Sediments
Unified Soil Classification System
SEDIMENT CHARACTERISTICS
Compactness of Coarse-grained Sediments
Gradation Fineness of Coarse-grained Sediments
Angularity of Coarse-grained Sediments
Consistency of Fine-grained Sediments
Plasticity of Fine-grained Sediments
Liquidity Index of Fine-grained Sediments
EXCAVATION PHASE DREDGEABILITY
Cuttability
Plain Suctionability
Erodability (Scourability)
Flowability of Underwater Slopes
Scoopability (Diggability)
REMOVAL AND TRANSPORT PHASE DREDGEABILITY
Pumpability in a Pipeline
Clay Balling Capability
Abrasiveness in a Pipeline
Sedimentation Rate in a Hopper
Building Rate in a Hopper
(Continued)

Table 2 (Concluded)
DISPOSAL PHASE DREDGEABILITY
Turbidity
Stickiness During Disposal
Sedimentation Rate in a Disposal Area
Bulking in a Disposal Area
Mechanical Compactability
SUITABILITY OF DREDGE TYPES
General Discussion of Dredge Suitability
Relative Digging Capability of Shovel, Backhoe and Bucket-Ladder Dredges
Relative Digging Capability of Clamshell and Dragline Dredges
Hopper - Trailing Arm Suction Hopper Dredges
Hopper - Plain Suction Hopper Dredges
Hopper - Bucket-Type Hopper Dredges
Mechanical - Backhoe Mechanical Dredges
Mechanical - Bucket Ladder Mechanical Dredges
Mechanical - Clamshell (Grab) Mechanical Dredges
Mechanical - Power Shovel (Dipper) Mechanical Dredges
Mechanical - Dragline Mechanical Dredges
Pipeline - Cutterhead Suction Pipeline Dredges
Pipeline - Plain Suction Pipeline Dredges
Pipeline - Dustpan Suction Pipeline Dredges
Pipeline - Bucket-Wheel Suction Pipeline Dredges

memo fields. The control buttons permit scrolling through the records of the database, each record having a local interest group name, date last amended, amender's name, and a scrollable text display of the information. The control buttons are: **< FIRST >** causes the record pointer to display the topmost, or first, record; **< PRIOR >** goes to the previous record; **< NEXT >** goes to the next record; **< LAST >** causes the record pointer to go the final, or bottom, record, and **< ADD TOPIC >** causes a new record to be added to the end of the others and to be displayed so that a new topic can be entered with new information. This button will not be operative if the database is rendered "read-only" by the action of a local program administrator.

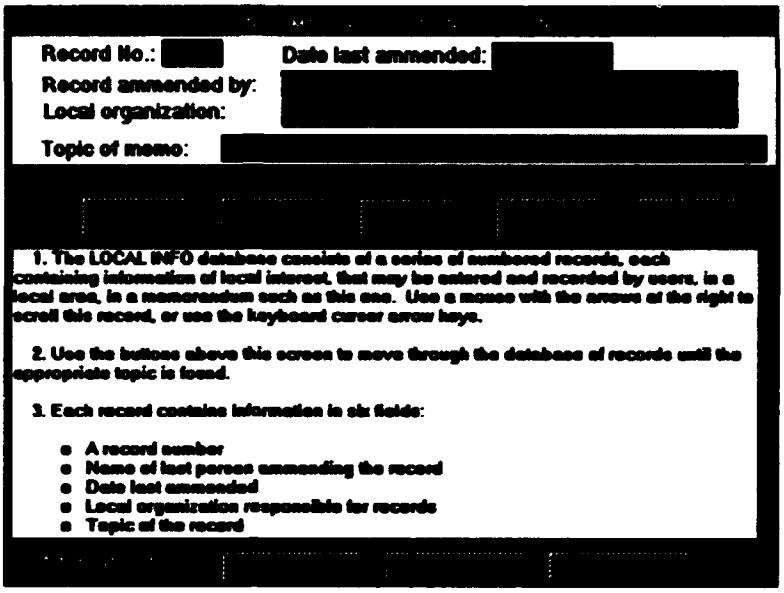


Figure 16. Selector screen for viewing/printing local information database records

Entry of information into this database is under the control of the user, unless a local DREDGABL program administrator assumes control of input. Modifications of, and additions to, the local information database may then be restricted to the local administrator. Methods for performing these tasks are discussed in Chapter 5.

4 The DREDGABL Programming Environment

This part of the user's guide contains background information used in the development of the DREDGABL program. Topics discussed are: (1) knowledge-based expert systems in general, (2) reasons for selection of the Microsoft FoxPro operating environment as an expert system shell, and (3) the relationship of this type of program to a published report.

Knowledge-Based Expert Systems

A KBES uses expert-derived rules for its solutions. The rules can incorporate and process judgement, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. During a guidance session, a KBES such as DREDGABL searches a knowledge base through a chain of IF - THEN rule statements. The logic of the arguments of the IF statements may be English words or phrases or may be numbers. The path through the matrix of rules is not pre-determined; rather, the path depends on the specific questions and on the user's replies, each of which lead to the next question and the next list of possible replies, as shown in Figure 1. In the KBES form used in DREDGABL, the program waits until all of the prerequisite IF questions have been asked, after which the answers are used to search the correct knowledge base for the appropriate THEN solution or group of solutions.

Expert systems generally contain a group of independent, but interrelated, components as shown in Figure 17. The USER INTERFACE interacts with the USER, employing an on-screen dialog for communication. When available, an on-screen HELP MEMO provides helpful information for making selections. Screens are also used display the conclusions reached by the program. The CONTROL PROGRAM AND INFERENCE ENGINE unit contains the control information that directs the flow of questions and conclusions. The program provides for interaction between the USER INTERFACE and the ANTECEDENT (CONTEXT) MEMORY. The CONTROL/INFERENCE mechanism is independent of the knowledge base, permitting modifications and additions to the conclusions contained in the knowledge base without modifying the program. The ANTECEDENT MEMORY, often called the CONTEXT, is a temporary memory containing the current answers to questions. The words, phrases, or numbers in CONTEXT must be standardized terms to match those in the knowledge base. The

KNOWLEDGE BASE contains all of the IF-THEN rules that are queried by the INFERENCE ENGINE using the antecedents stored in CONTEXT. The rules satisfying all of the antecedents are stored in CONCLUSIONS MEMORY, available for display on one or more conclusion displays at the USER INTERFACE.

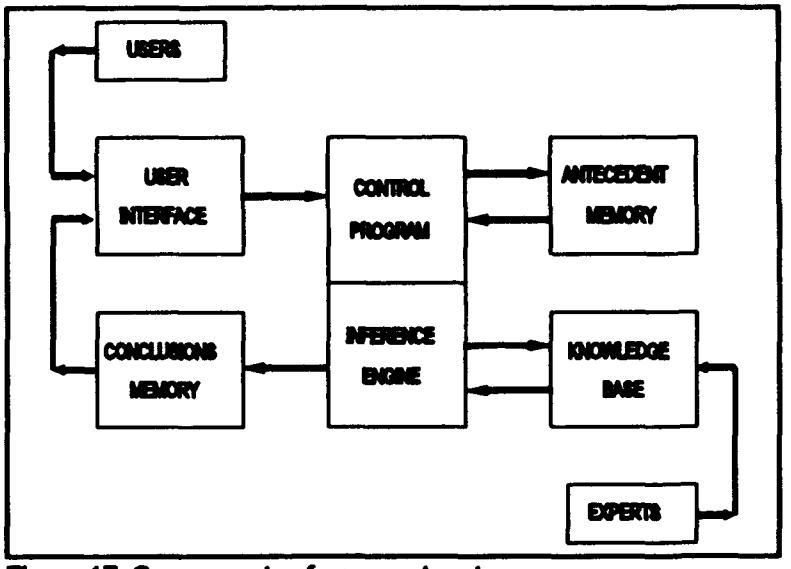


Figure 17. Components of an expert system

Selection of the Programming Environment

DREDGABL uses a forward-chaining, or data-driven, problem solving strategy. Knowledge representation is rule-based, each rule consisting of an "IF-antecedents . . . THEN-conclusion" statement. One rule exists for each of the total, finite number of options in the antecedents. In the present version of DREDGABL, there are 1010 unique sets of options. Ideally, each unique set of antecedent options leads to a single conclusion. DREDGABL reaches 27 different conclusions for each unique set of antecedents, for a total of 27,270 possible conclusions. Inferencing can, therefore, be done as a standard database search, using the antecedents (IF statements) as search filters to find the conclusion records (THEN statements) that satisfy all of the unique query requirements. By using 27 conclusion fields for each record, the total number of records to be searched is reduced to the 1037 possible sets of antecedents, greatly increasing the search speed of the system.

The programming environment chosen for the development of DREDGABL was the Microsoft FoxPro Relational Database Management System, a product of the Microsoft Corporation, Redmond, WA. FoxPro offers several desirable features:

a. FoxPro is a cross platform application, permitting the user a choice of either the MS-DOS or the popular Windows environment. FoxPro 2.5 for MS-DOS and FoxPro 1.0 for Windows are parallel systems, sharing control programs and databases. Display screens are also useable in either environment, although the graphical screens of Windows can use enhancements not available in MS-DOS displays.

b. The software vendor, Microsoft Corporation, is a large, secure company that is expected to be available for help and for future upgrades of the system. MS-DOS and Microsoft Windows are produced by the same company, ensuring cross-platform compatibility.

c. Knowledge can be represented in a database format (.DBF). The format used in FoxPro is compatible with the Borland dBase III and dBase IV databases. FoxPro can also import files from other popular software packages such as Framework II, Microsoft Multiplan, Borland Paradox, Lotus/Symphony and compatible spreadsheets, and Microsoft Excel. Any of these programs can then be used to access, and to modify, the knowledge bases (databases) in DREDGABL.

d. FoxPro contains a number of useful development aids, such as a screen development program, standard Xbase database programming, and a transporter program for converting, if desired, between MS-DOS and Windows screens.

e. Run-time versions of the programs (DOS and Windows) are distributed to users with the Microsoft FoxPro Distribution Kit for DOS and the Microsoft FoxPro Distribution Kit for Windows. A one-time fee for each Distribution Kit permits an unlimited number of distribution copies.

Even though DREDGABL was developed using a database management package, Microsoft FoxPro 2.5, it is still considered a KBES. The databases used in the inferencing contain subjective expert information compiled by the developers. Conclusions are reached using an inference mechanism and IF - THEN rules similar to any other expert system. In addition, DREDGABL is highly interactive, user friendly, and contains an on-line help facility, which are all essential features of a KBES.

Relationship to Published Reports

A KBES is, in effect, a technical report that has been placed into a computerized question-and-answer format. All of the information could, alternatively, have been contained in a written and published report. However, a computer-based KBES has certain advantages over the printed document:

a. The sequence of questions is expert-guided for each specific task. The user provides answers to the questions from an exhaustive, but limited, set of

correctly phrased answers, using standard terminology. When all appropriate questions have been asked and answered, the knowledge base is searched for all valid conclusions that can be derived from the problem context. The conclusions are presented on screen and, in some instances, can be printed.

b. It is simpler, easier, and faster to use than a published report. Pages appear on screen quickly rather than requiring hunting for the contents or index, then searching for the exact page, or pages.

c. The knowledge recorded in the knowledge base can be easily edited and modified to accommodate new research findings or local experiences, permitting the issuance of easily-made upgrade versions of DREDGABL on microcomputer diskettes. The text information contained in the readily-accessible "Discussion" topics can also be easily added to or changed. This does not imply that the user will be able to modify the control program or the knowledge base directly. Only the official, development version under the control of the developers or the program administrators will be capable of being modified.

d. For recording knowledge of a strictly local or regional interest, a separate "LOCAL INFO" discussion text knowledge base can be readily established and locally updated. Some organizations could benefit by placing the latest version of popular programs on a Local Area Network. In some instances, a national "bulletin board" system could be used to distribute the revised versions of the programs.

5 Modifying and Upgrading the DREDGABL Program

The program diskettes accompanying this user's guide are read-only, i.e., any changes entered onto the display screens during a guidance session cannot be stored. The original, development version of the program can only be modified by using the Microsoft FoxPro 2.5 Relational Database Management System. The original program diskettes reside with the Manager, Dredging Research Program, USAE WES, P. O. Box 631, Vicksburg, MS 39181-0631.

Request for User Evaluations

The rules developed for DREDGABL (Spigolon and Bakeer 1993) represent knowledge and expertise that was developed through professional experiences and research studies and, therefore, reflect the personal biases of the developers. The present rules should be critically reviewed by other geotechnical engineering and dredging experts and expanded or modified, as needed. In the ideal knowledge base, there are multiple experts who either reinforce each other or present valid alternate solutions to problems.

The authors request that users evaluate the program's usefulness, the screens, and the conclusions. There are many questions that can be asked by the developers, including the following:

a. Are there any other conclusion displays that would be meaningful, using the conclusions that are stored in the CONCLUSIONS MEMORY after a query?

b. Are there any more conclusions that should be drawn from the antecedents?

c. Is the information contained in the Conclusion displays sufficiently complete that the user can understand and then utilize the guidance correctly?

d. Are the program and the displays user-friendly?

e. What else can, or should, be done to improve the usefulness of the DREDGABL program?

The answers to these and other questions and any proposed changes should be sent to the Manager of the DRP at the address given above.

Modifying the LOCAL INFO Database

The only database file that can be directly modified by the user in the distribution copies of the DREDGABL program is the LOCLINFO.DBF file. This file is modified by directly typing onto the memorandum display screen, Figure 17. Instructions for this task are included as Record No. 1 and are also presented below. A total of 16 records have been established in this version of DREDGABL, of which the first is used for the instructions. If more than 15 additional records are needed, a provision has been made for adding records. Record numbers and dates should be added to all additional records. There is no practical limit to the number and size of records that can be added except the available space on the hard disk.

A local administrator may exercise input control by modifying the LOCLINFO.DBF database file attributes to make them read-only using a file management program such as Norton Commander® or Norton Utilities®, among others. Alternatively, similar programs may be used to require a password that can be supplied to the appropriate individuals.

Instructions for Modifying the LOCAL INFO Database

The instructions contained on Record No. 1 of the LOCAL INFO database are:

a. The LOCAL INFO database consists of a series of numbered records, each containing information of local interest, that may be entered and recorded by users, in a local area, in a memorandum such as this one. Use a mouse with the arrows at the right to scroll this record, or use the keyboard cursor arrow keys.

b. Use the buttons above this screen to move through the database of records until the appropriate topic is found.

c. Each record contains information in six fields:

1. A record number
2. Name of last person amending the record
3. Date last amended
4. Local organization responsible for records
5. Topic of the record
6. A variable length memorandum (in this area of the screen)

d. Unless *restricted*, information may be entered in any of the fields on this screen, or any other screen, by using the mouse or the < TAB > or < ARROW > keys to highlight a field. This information is stored directly in the LOCLINFO.DBF database. A local administrator may restrict modification of the records by making them "read only."

e. Sixteen records are provided in DREDGABL Version 1.0, this one plus fifteen more. At such time that additional records are needed, the button to the right above, marked < ADD TOPIC > may be used to append additional records to the database. There is no practical limit to the number or length of records except the space available for hard disk storage.

f. A copy of any of the individual records, with the complete memorandum, may be printed by clicking on the < PRINT > button below.

References

ASTM. (1993). "Natural building stones; soil and rock; geotextiles" *1993 Annual Book of ASTM Standards*, Volume 04.08, American Society for Testing and Materials, Philadelphia, PA.

Spigolon, S. J. and Bakeer, R. M. (1993). "Geotechnical factors in the dredgeability of sediments; Report 3, Guidance in the geotechnical evaluation of the dredgeability of sediments using GEODREDG," Contract Report DRP-93-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

USAEWES (1960). "The Unified Soil Classification System," Technical Memorandum No. 3-357, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Appendix A: Files Contained in the DREDGABL Distribution Diskettes

The following listing shows all of the files contained on the distribution diskettes for DREDGABL. If any of these files are missing or corrupted on your diskette, please contact the Manager of the Dredging Reseach Program at the USAE Waterways Experiment Station, Vicksburg, MS. The phone number is 601-634-2070.

DOS version of DREDGABL

DISK NO. 1:	FOXDISTR.ARC
	INSTALL..BAT
	INSTDR.BAT
	ARCE.COM
	START.BAT
	READ.ME
DISK NO. 2:	DOSDREDG.ARC
	ARCE.COM
	START.BAT
	READ.ME

Windows Version of DREDGABL

DISK NO. 1:

msetup .su
mstest .ex
commdlg .dl_
config .fp$
ddeml .dl_
dredgabl. ex$
foxfont .fo$
foxprint .fo_
foxprint .tt_
foxuser .db$
foxw250a.es$
loclinfo .db$
loclinfo .fp$
loclinfo .fr$
loclinfo .ft$
loclinfo .qp$
loclqury .db$
loclqury .fp$
msconstf .dl_
msculstf .dl_
msdetstf .dl_
msinsstf .dl_
msshlstf .dl_
msuilstf .dl_
olecli .dl_
olesvr .dl_
query .db$
setup .exe
setup .in_
setup .inf
setup .lst
setup .ms_
shell .dl_
toolhelp .dl_
ver .dl_

DISK NO. 2:

dredgab2 .es$
foxw2502.es$
foxw2503.es$
foxw2504.es$

Appendix B: Geotechnical Properties Affecting Dredgeability

The following summary discussion is background information, presenting terminology and concepts used in the development of the DREDGABL knowledge bases. ***Dredgeability*** is defined as the facility with which an underwater soil sediment or rock can be excavated, removed, transported, and deposited with respect to known or assumed equipment, methods, and in-situ material characteristics. There are several independent, site specific factors that affect dredgeability. *DREDGABL considers only the direct effect of soil type and character on dredgeability, separate from all non-sediment factors that affect dredging productivity, such as equipment characteristics, water depth, weather, tides, traffic, personnel problems, equipment maintenance, and so forth.*

The process of dredging an underwater sediment typically occurs in four stages. At each stage, the dredging process is affected by one or several dredgeability properties of the sediment. The processes and the associated dredgeability properties are:

a. **Dislodgement**--loosening or excavation of material from its location at or below the bottom. Dislodgement is affected by the suctionability, erodability, cuttability, scoopability, and flowability (underwater slope instability) properties of the sediment.

b. **Removal**--movement of the excavated material from the bottom up to the pump or transport system. The removal process is dependent on the pumpability, abrasiveness, stickiness (affects clay balling), turbidity, and bulking properties of the sediment.

c. **Transport**--movement of the removed material from the dredge to the disposal site. Transport is affected by the pumpability, abrasiveness, stickiness (affects clay balling), turbidity, sedimentation rate in a hopper, and bulking properties of the sediment.

d. **Disposal**--discharge of the material onto a land or into a water disposal area. The disposal area properties of a sediment are based on its dumpability (stickiness), turbidity potential, sedimentation rate in a land disposal site, bulking factors, and mechanical compactability.

Rule tables were prepared for use in the development of the DREDGABL knowledge bases and to demonstrate the basis for the dredgeability evaluations of the geotechnical properties of sediments. All of the rules in the tables are based on literature surveys and on the expertise of the program developers. The significance of the geotechnical properties requested during the operation of DREDGABL on each of the dredgeability properties is shown in Tables B1 and B2 below.

Table B1
Geotechnical Properties Used in the Dredgeability Rules For a Coarse-Grained Sediment

Dredgeability Property	Name and USCS Class	Compact-ness	Gradation Fineness	Angularity
EXCAVATION PHASE				
Cuttability	X	X	X	
Erodability	X	X	X	
Flowability	X	X	X	
Scoopability	X	X	X	
Suctionability	X	X	X	
REMOVAL/TRANSPORT PHASE				
Abrasiveness	X			X
Clay Balling Potential	X			
Pumpability	X			
Sed. Rate in Hopper	X			
Bulking in Hopper	X	X		
DISPOSAL PHASE				
Stickiness	X			
Sed. Rate in Disposal	X			
Turbidity Potential	X			
Bulking in Disposal Area	X	X		
Compactability	X			

Table B2
Geotechnical Properties Used in the Dredgeability Rules For a Fine-Grained Sediment

Dredgeability Property	Name and USCS Class	Consist-ency	Plasticity Index	Liquidity Index
EXCAVATION PHASE				
Cuttability	X	X		
Erodability	X	X		
Flowability	X	X	X	
Scoopability	X	X	X	
Suctionability	X	X	X	
REMOVAL/TRANSPORT PHASE				
Abrasiveness	X			X
Clay Balling Potential	X			
Pumpability	X			
Sed. Rate in Hopper	X			
Building in Hopper	X	X		
DISPOSAL PHASE				
Stickiness	X			
Sed. Rate in Disposal	X			
Turbidity Potential	X			
Building in Disposal Area	X	X		
Compactability	X			

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1994	Final Report

4. TITLE AND SUBTITLE
DREDGABL: Geotechnical Factors in Dredgeability; User's Guide

5. FUNDING NUMBERS
WU 32471

6. AUTHOR(S)
S. Joseph Spigolon, Reda M. Bakeer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
SJS Corporation, 2220 No. 13th Court, Coos Bay, OR 97420;

Department of Civil and Environmental Engineering,
Tulane University, New Orleans, LA 70118

8. PERFORMING ORGANIZATION REPORT NUMBER
Instruction Report
DRP-94-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station,
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Geotechnical Factors in DREDGeABiLity (DREDGABL) Program provides guidance in the interpretation of geotechnical descriptors of sediment in terms of their dredgeability properties. It is intended to be used by engineers, estimators, and contractors, serving as a personal geotechnical engineering consultant.

14. SUBJECT TERMS
DREDGABL
Dredgeability
Geotechnical descriptors
Knowledge-based expert systems

15. NUMBER OF PAGES
45

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		